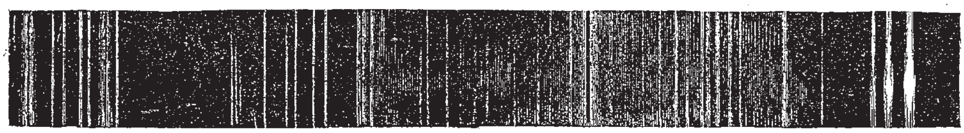
out by means of the accompanying copy of a photograph. A small mass of metallic calcium has been placed between the two poles of an electric lamp. By means of the passage of the current this mass of calcium has been raised to a very high temperature, and it has been driven to its ultimate fineness,—it has been driven, in fact, to a state of vapour competent to give out very thick bright lines in the regions marked *a*, *b*, *c* (Fig. 6.) As the vapour is gradually given off from the mass of metallic calcium, it has surrounded the interior part, and has gradually cooled as it got away from the action of the electricity. So that here we have an intensely heated mass of calcium vapour in the centre surrounded by a mass of calcium vapour which is cooling.

We have, therefore, between us and the central mass a screen of calcium molecules under exactly the same conditions as those we suggested in the screen of molecules giving out yellow light lying between us and a distant light source.

What then are the facts? On the photograph three



b *a*

Fig. 6.—Reversal of the light of hot calcium vapour by cool calcium vapour.

bright broad bands of light are seen in different parts of the spectrum, which represent three of the characteristic bands of the metal calcium. I want especially to call attention to the fact that in the middle of these bands, especially in the one lettered *a*, there is a fine line of intense blackness.

That is to say, in that particular region of the spectrum there has been no light to paint an image of the slit. What has become of that light? The light has been at work, not on the photographic plate, but among the cooler exterior molecules of calcium which have used it up.

I shall now take it for granted that the great principle, that molecules absorb the light passing through them in the same wave lengths as those which they give out when vibrating on their own account, has been rendered familiar.

We must not forget that this statement is only true so long as the molecular combinations are the same, and that we only get this result in the shape of bright lines when we are dealing with the ultimate finenesses of each chemical substance, that is, when we are dealing with each chemical substance in a state of vapour.

Without going further, then, it is clear that we are now in presence of two causes of coloured light as opposed to white light. There is, so to speak, a cause of *ef*fect and a cause of *de*fect. We now know of one reason why light may be red: the luminous vibrating substance may only be competent to vibrate at that particular rate which gives us the sensation of red light. But this is not the only reason why light may be red. If we assume a screen so constituted that all the light proceeding from a white light source, *except the red*, should be absorbed by the screen, we have there a condition in which the sensation of red would again be produced. In this case it will not be the *ef*fect of red vibrations alone in the light source, but by virtue of the *de*fect of all the others which we have assumed to be absorbed by the screen.

In both cases we arrive at

V I B G Y O R

in the first case because the only light given us is

R

in the second because the screen vibrates only in

V I B G Y O

and therefore only absorbs these colours.

Red fire in a pyrotechnic display is an example of the first case. The setting or rising sun is an example of the second.

The expenditure of a very small amount of money and time will enable any one to become acquainted with many of these phenomena. The best spectroscope after all, perhaps, ease of manipulation being taken into account, is a prism held close to the eye, and a fine slit, say one-twentieth of an inch broad and two inches long, carefully cut out of a piece of tin-foil, gummed on a plate of glass. When this slit, say a foot off, is observed with the refracting angle of the prism parallel to its length, a very brilliant spectrum of a candle just in front of the slit is obtained, even though it be wanting in definition. This latter can of course be improved if a narrower slit be employed: for in spectra all impurity comes from overlapping of images, and the operations of Nature are so fine that it seems as if a pure colour, such as a pure blue or a pure red, will for ever remain an abstraction; for, however great the dispersion, the adjacent wave-lengths will remain commingled, and commingled wave-lengths define a compound colour.

Instead of reducing the width of the slit, if it is not connected with the prism by means of a tube, as it may conveniently be, the slit can be removed further from the prism. In this way we get apparently a narrower slit without any reduction in the quantity of light which passes through it to the eye. A gas flame or a candle placed in front of this slit is all that is necessary to produce a continuous spectrum.

J. Norman Lockyer

CLIFFORD'S DYNAMIC

Elements of Dynamic. Part I. Kinematic. By W. K. Clifford. (London: Macmillan and Co., 1878.)

Though this preliminary volume contains only a small instalment of the subject, the mode of treatment to be adopted by Prof. Clifford is made quite obvious. It is a sign of these times of real advance, and

will cause not only much fear and trembling among the crammers but also perhaps very legitimate trepidation among the august body of Mathematical Moderators and Examiners. For, although (so far as we have seen) the word quaternion is not once mentioned in the book, the analysis is in great part purely quaternionic. And it is not easy to see what arguments could now be brought forward to justify the rejection of examination-answers given in the language of quaternions—especially since in Cambridge (which may claim to lay down the law on such matters) Trilinear Cöordinates, Determinants, and other similar methods were long allowed to pass unchallenged before they obtained formal recognition from the Board of Mathematical Studies.

Every one who has even a slight knowledge of quaternions must allow their wonderful special fitness for application to Mathematical Physics (unfortunately we cannot yet say Mathematical *Physic!*): but there is a long step from such semi-tacit admissions to the full triumph of public recognition in Text-Books. Perhaps the first attempt to attain this step (in a book not ostensibly quaternionic) was made by Clerk-Maxwell. In his great work on *Electricity* all the more important Electrodynamic expressions are given in their simple quaternion form—though the quaternion *analysis* itself is not employed:—and in his little tract on *Matter and Motion* (NATURE, vol. xvi. p. 119) the laws of composition of Vectors are employed throughout. Prof. Clifford carries the good work a great deal farther, and [if for this reason alone] we hope his book will be widely welcomed.

To show the general reader how much is gained by employing the calculus of Hamilton we may take a couple of very simple instances, selecting them not because they are specially favorable to quaternions but because they are familiar in their Cartesian form to most students. Every one who has read *Dynamics of a Particle* knows the equations of non-acceleration of moment of momentum of a particle, under the action of a single centre of force, in the form

$$\left.\begin{aligned} x\ddot{y} - y\ddot{x} &= 0 \\ y\ddot{z} - z\ddot{y} &= 0 \\ z\ddot{x} - x\ddot{z} &= 0 \end{aligned}\right\}$$

with their first integrals, which express the facts that the orbit is in a plane passing through the centre, and that the radius-vector describes equal areas in equal times. But how vastly simpler as well as more intelligible is it not to have these *three* equations written as *one* in the form

$$V\rho\ddot{\rho} = 0$$

and the three first integrals above referred to as the immediate deduction from this in the form

$$V\rho\dot{\rho} = \alpha.$$

Take again Gauss's expression for the work done in carrying a unit magnetic pole round any closed curve under the action of a unit current in any other closed circuit. As originally given, it was

$$\iint \frac{(x^1-x)(dydz^1-dzdy^1)+(y^1-y)(dzdx^1-dxdz^1)+(z^1-z)(dxdy^1-dydx^1)}{\left((x^1-x)^2+(y^1-y)^2+(z^1-z)^2\right)^{\frac{3}{2}}}$$

With the aid of the quaternion symbols this unwieldy expression takes the compact form

$$\iint \frac{S.\rho\, d\rho\, d^1\rho}{T\rho^3}.$$

The meanings of the two expressions are identical, and the comparative simplicity of the second is due solely to the fact that it takes space of three dimensions as it finds it; and does not introduce the cumbrous artificiality of the Cartesian cöordinates in questions such as this where we can do much better without them.

In most cases at all analogous to those we have just brought forward, Prof. Clifford avails himself fully of the simplification afforded by quaternions. It is to be regretted, therefore, that in somewhat higher cases, where even greater simplification is attainable by the help of quaternions, he has reproduced the old and cumbrous notations. Having gone so far, why not adopt the whole?

Perhaps the most valuable (so far at least as physics is concerned) of all the quaternion novelties of notation is the symbol

$$\nabla = i\frac{d}{dx} + j\frac{d}{dy} + k\frac{d}{dz},$$

whose square is the negative of Laplace's operator: *i.e.*

$$\nabla^2 = -\left[\left(\frac{d}{dx}\right)^2 + \left(\frac{d}{dy}\right)^2 + \left(\frac{d}{dz}\right)^2\right].$$

A glance at it is sufficient to show of what extraordinary value it cannot fail to be in the theories of Heat, Electricity, and Fluid Motion. Yet, though Prof. Clifford discusses Vortex-Motion, the Equation of Continuity, &c. we have not observed in his book a single ∇. There seems to be a strange want of consistency here, in coming back to such "beggarly elements" as

$$\delta_x u + \delta_y v + \delta_z w$$

instead of

$$-S\nabla\sigma,$$

especially when, throughout the investigation, we have σ used for

$$ui + vj + wk;$$

and when, in dealing with strains, the Linear and Vector Function is quite freely used. Again, for the vector axis of instantaneous rotation of the element at x, y, z (ρ), when the displacement at that point is $\sigma = iu + jv + kw$, we have the cumbersome form

$$\tfrac{1}{2}\left\{(\delta_y w - \delta_z v)\, i + (\delta_z u - \delta_x w)\, j + (\delta_x v - \delta_y u)\, k\right\}$$

instead of the vastly simpler and more expressive

$$\tfrac{1}{2} V\nabla\sigma.$$

It may be, however, that this apparent inconsistency is in reality dictated by skill and prudence. The suspicious reader, already put on his guard by Clerk-Maxwell's first cautious introduction of the evil thing, has to be treated with anxious care and nicety of handling:—lest he should refuse altogether to bite again. If he rise to the present cast we shall probably find that Prof. Clifford has ∇, in the form as it were of a gaff, ready to fix him irrevocably. That he will profit by the process, in the long run, admits of no doubt:—so the sooner he is operated on successfully the better. What is now urgently wanted, for the progress of some of the most important branches of mathematical physics, is a "coming" race of intelligent students brought up, as it were, at the feet of Hamilton; and with as little as may be of their freshness wasted on the artificialities of x, y, z. Till this is procured, quaternions cannot have fair play. Nut-cracking,

though occasionally successful for a moment, is the most wasteful and destructive of all methods of sharpening the teeth.

What we have at some length discussed is the most prominent feature of the present work, but by no means its only distinctive one. No writer, who has any claim upon his readers at all, can treat even the most hackneyed subject without giving a new and useful turn to many a long-known truth. Many of Prof. Clifford's proofs are exceedingly neat, and several useful novelties (*e.g.* Three-bar Motion) are introduced. We have to complain, however, of a great deal of unnecessary new and very strange nomenclature:—for a large part of which the author is not responsible, his error (for such we cannot help considering it) consisting in giving this stuff a place of honour in his book. One does not require to be very violently conservative to feel dismayed at an apparently endless array of such new-fangled terms as Pedals, Rotors, Cylindroids, Centrodes, Kites, Whirls, and Squirts! Yet these are but a few gleaned at random from the book. Something, it seems, *must* be hard in a text-book—simplify the Mathematic, and the Anglic (*i.e.* the English) immediately becomes perplexing. P. G. TAIT

PHYSICS OF VOLCANOES

Beitrag zur Fysik der Eruptionen und der Eruptiv-Gesteine. Von Dr. Ed. Reyer, Docent an der Universität in Wien. (Vienna: Alfred Hölder, 1877.)

DR. Reyer, of Vienna, has already made his mark in geological literature by the admirable work entitled "Die Euganeen: Bau und Geschichte eines Vulcans," in which he has given a very clear and instructive interpretation of the phenomena presented by that grand tertiary volcano of Northern Italy, of which the internal structure has been so well displayed to the geologist through the agency of denuding forces. Those who are acquainted with the merits of the first published work of Dr. Reyer will eagerly take up the volume which has now made its appearance, the title of which stands at the head of the present notice; nor will their anticipations that a difficult question will meet with masterly and original treatment at the hands of its author be disappointed.

A starting-point for a series of discussions of the phenomena of volcanic action and the causes to which these are due is found by Dr. Reyer in the demonstrated capacity of various substances in a state of igneous fusion for absorbing certain gases. If the suggestion that in this peculiar property of bodies in a state of fluidity under the action of heat we find a key to many of the most remarkable phenomena of volcanic eruptions be not altogether new, it must at least be admitted that it has never before received such ample discussion and illustration as it now undergoes in the hands of Dr. Reyer, and even still less has hitherto been done in applying the explanation in question to these numerous minor and concomitant phenomena which precede, accompany, and follow volcanic outbursts.

In the first part of the work before us, the author, after citing the interesting observations of Gay Lussac, Fournet, Thenard, Réaumur, and other chemists, in proof of the property of absorption as displayed by substances in a state of igneous fusion, goes on to show that many of the striking appearances exhibited during volcanic eruptions clearly point to the conclusion that a highly-heated magma within the earth's crust has, through infiltration, become charged with liquid and gaseous materials. He then proceeds in the second part of the volume to show how many of the phenomena of volcanoes—such as the succession of events in the history of their formation and in that of each individual eruption, the peculiarities of the internal structure of volcanoes and of the masses of lava extruded from their vents, and the nature of the gaseous exhalations which accompany the outbursts during their several stages—receive a simple explanation from this remarkable property exhibited by substances in a state of fusion.

Apart, however, from the value of its more speculative portions, Dr. Reyer's work will be welcomed by geologists as bringing together in a connected form all the most important of the recent observations which have been made upon the nature and products of volcanic activity. It is in this respect that the third part of the work before us, that which deals with the peculiarities of volcanic rocks, appears to us to be especially worthy of attention. The author not only admits that the principle which has been so long followed by German petrographers, of basing the classification of igneous rocks on their geological age, is altogether untenable, but he goes farther and strongly denounces the mischievous tendencies of this method in obscuring some of the most striking inferences to be derived from the exact study of such rocks. Strongly insisting on the fact that portions of the same magma may, under different physical conditions, assume a granitic, a porphyritic, or a vitreous structure, Dr. Reyer shows clearly how the various igneous intrusions found associated with sedimentary deposits were in all probability originally connected with centres of volcanic activity; and he also shows the grounds for the inference that masses of granitic structure are being formed at the present day by the slow consolidation under pressure of portions of the magma below the existing volcanic vents.

Of the urgent necessity for reforms in our petrographical nomenclature, the author of this work, holding the views he does, clearly perceives the necessity; and his suggestions upon the subject deserve, as they doubtless will receive, the careful attention of geologists. Some of the interesting relations between the structure and composition of rocks are, we may remark in passing, very well illustrated by the series of ingenious diagrams which accompany this volume. J. W. J.

OUR BOOK SHELF

Travels in the Footsteps of Bruce in Algeria and Tunis; Illustrated by Facsimiles of his Original Drawings. By Lieut.-Col. R. L. Playfair, H.B.M. Consul-General in Algeria. (London: C. Kegan Paul and Co., 1877.)

THE northern regions of Africa that border on the Mediterranean Sea would form a deeply interesting study for the historian. Perhaps no other portion of the world's surface has passed through more marked phases of civilisation, yet all of these have passed away and left but small trace behind them. Placed between a wondrously teeming offshoot of the Broad Atlantic